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NASA TECHNICAL MEMORANDUM

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ASPECTS OF ANNOYANCE DUE TO NOISE
OF ROAD TRAFFIC. SURVEY RESULTS
AT 10 SITES

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d'enquêtes sur 10 sites". Ministère de
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16. Abstract The most significant results from a study by the Transportation Research Institute are summarized for the interest of major highway contractors. The study presents the sites investigated, and the method of study. Results of surveys per site are given. A discussion is given of factors studied such as contribution of various noise sources, variation of noise levels at different sites, times and activities disturbed, and noise level and annoyance.			
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ASPECTS OF ANNOYANCE DUE TO NOISE OF ROAD TRAFFIC

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PURPOSE OF DOCUMENT

"Annoyance caused by noise" . . . each one of us has had a personal experience of it and can cite multiple aspects.

But when this problem is brought up, either technical considerations soon make it an area reserved to specialists or one is content with general remarks that do not go much further than parlor conversation.

And yet, studies have been conducted both in France and abroad in the last few years to describe different aspects of annoyance caused by noise, especially that caused by road traffic.

The results of several studies and surveys conducted in this area by the Scientific and Technical Building Center (CSTB) have been published in its bulletins, particularly number 762 of October, 1967⁽²⁾, and number 1174 of April, 1973⁽³⁾.

The Transportation Research Institute (IRT-CERN/National Highway Research Center) conducted an extensive survey at the request of the Ministry of Equipment (SETRA), its purpose being to better specify different aspects of annoyance caused by traf-

* Numbers in margin indicage pagination of foreign text.

(2) "Annoyance Caused by the Noise of Automobile Traffic: Survey of Persons Living Near Expressways", by Messrs. Lamure and Bacelon.

(3) "The Street Noises and Annoyance Expressed by Persons Living Along the Streets", by Messrs. Aubree, Aužou and Rapin.

fic noises; to establish additional elements affecting annoyance/3 noise level correlation; and to furnish data on attitudes of persons living near arterial highways. These surveys were conducted in greatly different locations chosen from among both small towns and large urban centers.

Such studies are undeniably valuable to services charged with the setting up of urban expressways and the improvement of existing highway networks in large urban centers.

For this reason, the most significant of results from the IRT's most recent study have been summarized and described herein for the interest of major highway contractors.

This document sets forth objective testimony, based on statistics, relative to attitudes of persons residing near important highways, with respect to annoyance caused by traffic noise.

The question is not the precise definition of desirable noise level thresholds through generalization of conclusions drawn from IRT-CERN's rigorously conducted study, although it makes possible specification of certain physical data that is a requirement for all past and future investigations that satisfactorily establish annoyance/noise correlation. The question is, rather, to combine data that is both objective (analyzing survey responses) and subjective (extractions from responses of persons interviewed) for provision of concrete, significant indications that make it possible to ascertain reactions to noise by persons living near expressways, as well as their views on changes in their environment due to construction of such highways.

This part includes three chapters:

- Sites Studied
- Methods of Study
- Organization of Forms

SITES STUDIED

1.1. Choice of Sites.

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A range of sites with the most widely-varying characteristics was selected, requiring further classification sufficient to permit clear conclusions to be drawn from their examination. Primary selection criteria pertained to:

- the dominant collective or villa aspect of the district;
- dates of construction of the buildings;
- types of roads passing through the site, e.g., roads of traditional configuration (avenues with dense traffic) distinguished from expressways (rapid-traffic urban roads) or mixed roads (avenues designed to accommodate considerable traffic, without combining characteristics of an expressway).

Furthermore, the sites selected show a large variation of noise levels. Indeed, the survey areas represent a continuous scale of acoustic levels, starting at a level considered as acceptable, and extending up to a level difficult to tolerate.

Within one site, noise levels can also vary considerably (from 59 to 74 dB(A) in Bourg-en-Bresse), depending on distance from the road. This made it possible to question persons in different acoustic situations within the same site.

Surveys were conducted in ten cities:

-- Dijon	(Avenue du Drapeau)
-- Clermont-Ferrand	(Boulevard Loucheur)
-- Bourg-en-Bresse	(Boulevard E. Herriot)
-- Lyon-Villeurbanne	(Boulevard de Ceinture)
-- Nimes	(South Peripheric Road)
-- Nantes	(Avenue Charles de Gaulle)
-- Paris region	(West Expressway, intersection of Fontenay-le-Fleury, St. Cyr-l'Ecole)
-- Saint Etienne	(Expressway A47, intersection of la Marandiniere)
-- Givors	(Expressway A47-C47)
-- Metz	(East Penetration Highway)

1.2. Characteristics of the Sites.

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The survey sites may be classified as follows, by nature of housing and type of road:

Nature of Housing	Type of road	Traditional Road (1)	Mixed Road (2)	Urban Expressway (3)
COMPACT APARTMENT BUILDING		DIJON BOURG-EN-BRESSE	LYON- VILLEURBANNE NIMES	PARIS REGION
VERY WELL SPACED APARTMENT BUILDING			NANTES	SAINT ETIENNE
VILLA TYPE AND MIXED		CLERMONT- FERRAND		GIVORS METZ

- (1) Dense traffic avenues.
- (2) Avenues designed to accommodate considerable traffic, without combining all characteristics of expressways.
- (3) Expressways.

They may also be classified according to the traffic passing on the expressway and the noise levels in the site:

Site Studied	Total Traffic (TMJA*) and Date of Data	Percentage of Trucks Counted on Day of Acoustic Measurements	Noise Levels in L_{eq} 8:00 AM - 8:00 PM (On facades of buildings surveyed.)
DIJON	12,000 (1971)	17%	59 to 74 dB (A)
CLERMONT-FERRAND	13,250 (1974)	5%	62 to 71 dB (A)
BOURG-EN-BRESSE	13,900 (1971)	21%	59 to 74 dB (A)
LYON-VILLEURBANNE	41,500 (1974)	12%	59 to 65 dB (A)
NIMES	23,800 (1972)	20%	65 to 74 dB (A)
NANTES	38,000 (1972)	8%	62 to 71 dB (A)
PARIS REGION	48,000 (1971)	16%	65 to 71 dB (A)
SAINT ETIENNE	18,700 (1971)	15%	62 to 68 dB (A)
GIVORS	17,860 (1973)	25%	68 to 74 dB (A)
METZ	22,200 (1972)	11%	49 to 71 dB (A)

*TMJA: Average Annual Daily Traffic

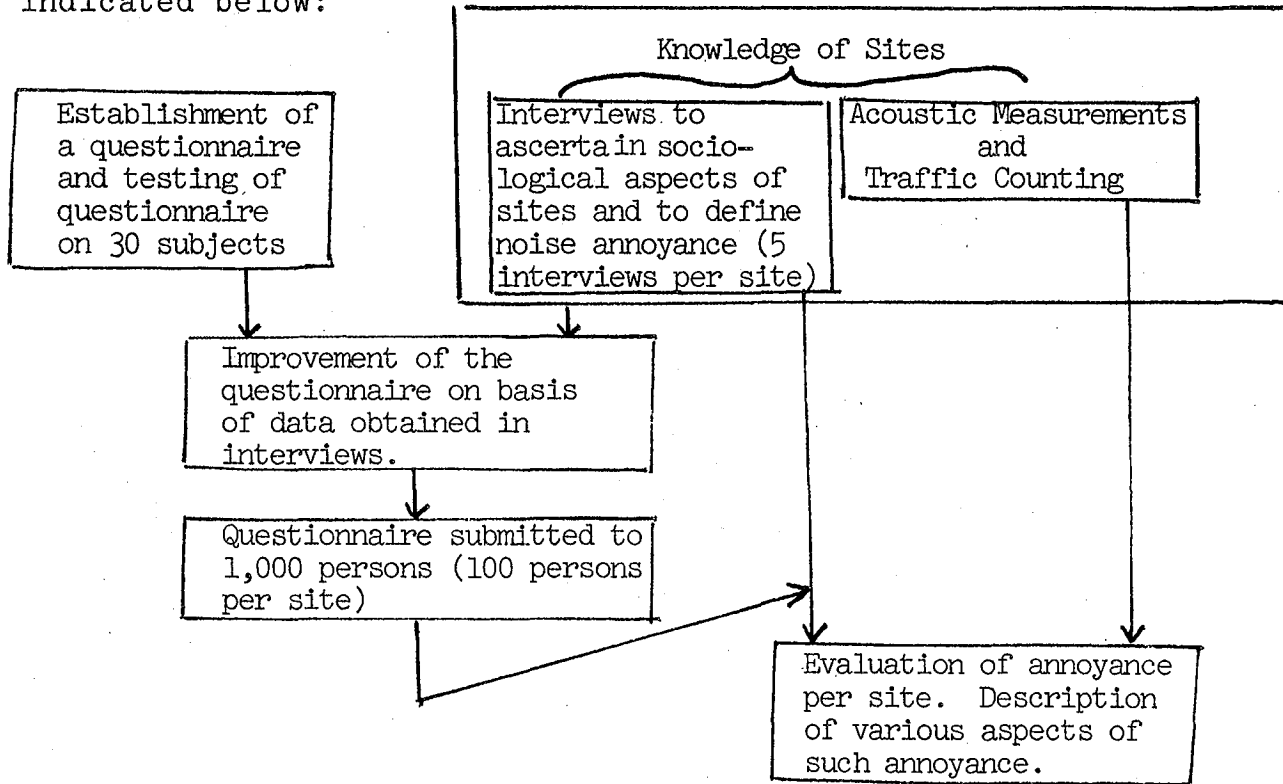
METHOD OF STUDY

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The method established to define different aspects of annoyance relating to road traffic noise in the ten selected sites

combines noise level measurements and traffic counting with an assessment of annoyance by means of interviews and questionnaires.

The different phases of the study may be summarized as indicated below:



The study, therefore, covered three different sectors:.

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=

- Psycho-sociological analysis
- Measurement of noise levels
- Counting of traffic

For each of these sectors, we will briefly describe below the method used.

2.1. Psycho-Sociological Analysis

a. Adjustment of questionnaire.

A first questionnaire was established on the basis of thorough study of documents (previous investigations published in France and abroad) and precise definition of objectives of the study. This questionnaire tested 30 subjects.

b. Interviews to become acquainted with site.

PURPOSE OF INTERVIEWS

Altogether, fifty interviews were made at the rate of five per site, to learn the background of persons living near roads in those sites. They were to provide a general view of the districts studied, as well as the manner in which they were perceived by those who reside there, with particular analysis given:

- type of housing, concept of district, district/city relationships;
- extent of economic and socio-cultural facilities;
- history of district's establishment and layout of roads.

They also enabled us to explore annoyance attributed to expressway noise:

- by identifying specific aspects of this annoyance, e.g., through description of behavior disturbed, search for primary causal elements of the annoyance and its consequence on life in the district, etc.;

- by seeking relative extents of annoyances caused by traffic noise, compared to characteristics of the district, satisfaction (or dissatisfaction with housing), the district, etc.

TECHNIQUE USED

Interviews were conducted as semi-guided or centered, alternating between guided and unguided periods. The interviewer was required to bring up a certain number of topics, then allow the subject to talk freely on these topics. Interviews were analyzed by IRT socio-psychologists, using an analysis system they had established and which we adopted to structure responses to the survey according to site.

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The system included three large topics:

- satisfaction with regard to district and residences;
- annoyance and noise;
- attitude with respect to the road.

A two-pole coding (negative and positive) according to whether the person interviewed is satisfied or dissatisfied, led to assessment of a given site, i.e., the positive or negative attitude of the people on each of these topics.

c. Questionnaire.

The questionnaire was distributed among 1,000 persons, at the rate of 100 persons per site. After a first phase (300 questionnaires), a coding plan was established which made it possible

to specify instructions to persons conducting the interviews.

The questionnaire contained 60 questions, grouped into topics:

- 13 questions on annoyance (degree and description of annoyance suffered, cause of annoyance and period disturbed);
- 19 questions relating to attitude about the road;
- 20 questions concerning variables other than noise, e.g., district, environment and lifestyle;
- 8 questions concerning individual characteristics of persons interviewed.

It was filled in by the interviewer questioning persons chosen at random in the studied site. Thus, the survey included not only those who felt concerned (positively or negatively) about the problem but also took into account responses from persons who were scarcely concerned at all, for overall analysis of community reactions to the road.

The responses were numerous enough to require use of an informatic procedure to analyze the results. This method was worked out at the IRT.

2.2. Measurement of Noise Levels.

To have a precise idea of noise levels existing in the ten selected sites, two types of measurements were carried out in each:

- Measurement of noise levels conducted continuously for a day and a night, at a point arbitrarily designated as the principal point, accompanied by simultaneous counting of vehicle traffic;
- Soundings lasting 15 minutes (five soundings for simple sites, 12 to 15 for complex sites), making it possible to learn noise levels at the facades of buildings included in the samplings as compared with measurements carried out simultaneously at the principal point.

Classical measurement instruments are used:

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- for continuous measurement, a sonometer-graphic recorder-statistical analyzer chain;
- for soundings, a high-quality magnetic-tape recorder.

All the statistical distributions relating to the sounding points and the samplings were then processed by computer.

The following indicators were calculated:

- indicators of statistical distribution:

L_1 = level reached or exceeded for 1% of the time;
 L_{10} = level reached or exceeded for 10% of the time;
 L_{50} = level reached or exceeded for 50% of the time;
 L_{90} = level reached or exceeded for 90% of the time.

- the equivalent acoustic level L_{eq} ;
- the mean quadratic deviation σ ;
- the "Noise Pollution Level", $LNP = L_{eq} + 2.56 \sigma$.

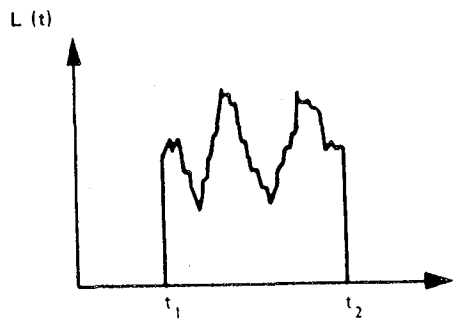
They were calculated for different times of the day, the time schedule adopted being as follows:

- 8 a.m. to 8 p.m.: daytime;
- 8 p.m. to midnight: time for rest and falling asleep;
- midnight to 5 a.m.: time of sleep;
- 5 am to 8 a.m.: time of waking and resumption of activities.

REMARK:

Exact definition of L_{eq} (sound level equivalent in energy) is given in Chapter I of the Guide to Noise.

As a reminder, we give a simpler expression for the definition of L_{eq} : assuming a noise level emitted during an interval of time $t_2 - t_1$ and varying as indicated in the following figure,



the level L_{eq} equivalent in energy is expressed as the level of constant noise which would have been furnished with the same energy during the interval $t_2 - t_1$.

In the forms per site which make up the second part of this document, the noise levels are expressed in L_{eq} , either for each hour or for the period of time indicated by the index.

2.3. Measurement of Vehicle Traffic

The previously described acoustic measurement enabled us

to find the noise level caused by traffic passing during a given interval of time.

To complete these noise measurements, traffic measurements are needed, satisfying a double purpose:

- Knowing in detail the vehicle traffic passing during acoustic measurements enables characterization of the function $L = f(Q)$ in a given site. (L represents the noise level, with Q being representative of different traffic characteristics).
- Knowing the distribution of hourly traffic components over the day, as well as the change in daily traffic components over the months, it is possible to derive the value of the average noise levels actually perceived over a long period by a person living near the studied road.

Therefore, we need two types of traffic measurements, and they were carried out on the various sites.

a. Measurements of vehicle traffic passing at the time of noise measurements.

It may be considered that the overall noise level caused by road traffic is really represented by four parameters relating to this traffic: number and speed of light vehicles, and number and speed of heavy vehicles (more than 3.5 tons loaded)⁽¹⁾.

At a given geometrical point, the relation $L = f(Q)$ may therefore be characterized by simultaneously measuring:

- the L_{eq} noise level in dB (A);

⁽¹⁾For more details, please refer to Chapter II of "Guide to Noise", 1976 edition.

- the number of light vehicles Q (VL);
- the speed of the light vehicles V (VL);
- the number of trucks Q (PL) (often expressed in % with respect to the total number);
- the speed of the trucks.

To distinguish between light vehicles (VL) and trucks (heavy vehicles = PL), the traffic count was carried out by use of the following method:

- counting of the total traffic (VL + PL) with pneumatic counters, per quarter of an hour;
- separate counting of truck traffic with manual counters, with the total of trucks obtained for every 15 minutes, according to acoustic measurements and counting of total traffic.

The speeds were roughly estimated by placing a vehicle in the line whose speed we wished to determine.

b. Distribution of hourly traffic during the day --
Change in daily traffic.

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For most of the important highways, there are permanent counts obtained by traffic bureaus of the various Departmental Equipment Boards. These permanent counts enable us to know:

- annual average daily traffic (TMJA), the value indicated in the forms per site;
- change in hourly traffic over the day, giving us the

peak structure, or, on the contrary, the spread of peaks of a given traffic, as well as the average traffic at the time of falling asleep and sleeping.

ORGANIZATION OF THE FORMS

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The main results of the interviews and of the survey by questionnaire have been summarized. A form was established for each of the 10 sites, on the basis of a single plan which includes:

a. General presentation of the example.

In this chapter, we describe briefly:

- the site: location in the city, description of buildings, the district, the residents, relationships between neighbors;
- the road: daily traffic, hourly traffic over 24 hours, percentage of trucks;
- the noise levels: variation of L_{eq} by quarters of an hour, at one point over 24 hours and noise levels found at building facades for the entire site.

This description is completed with illustrations: plan of the town at the scale of 1-100,000; plan of the district in which site is located; photo of the road and buildings; and curves of noise level and traffic variations over 24 hours.

b. Responses of persons to survey.

Responses of persons to the survey are summarized in the

form of a table, a curve and extracts of recorded interviews.

The table includes three lines:

- average noise levels measured in front of the facade of the most exposed building;
- number of persons questioned who are exposed to these noise levels;
- most frequent response with respect to annoyance.

For example, in Dijon the first column will be read as follows: 62% of the people questioned are exposed to a facade noise level (L_{eq} from 8 a.m. to 8 p.m.) of 74 dB (A).

The part of the community called upon by the questionnaire to express the annoyance they suffer responded "highly annoyed" in 60% of the cases. This response was chosen by interviewees from four choices: very annoyed, rather annoyed, hardly annoyed, not at all annoyed.

The table indicated that this was the most frequent response, i.e., among the persons in Dijon exposed to 74 dB (A), those who felt they are "highly annoyed" are most numerous (60%) while other chose one of the other responses. Conversely, 6% of those questioned in Dijon are exposed to a noise level of 59 dB (A) in the facade area, and in this part of the community, the most frequent response was "hardly annoyed" (50%).

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When two types of responses were expressed with the same frequency, they were indicated as such in the table. (Example: In Clermont-Ferrand, 38% of the persons exposed to 71 dB (A) feel highly annoyed, 38% feel rather annoyed, and the other 24% feel either slightly or not at all annoyed).

The annoyance curves constitute a graphic representation of the results contained in the table. They give a picture of the variation of the annoyance as a function of the noise levels in the facade area (L_{eq} from 8 a.m. to 8 p.m.).

The extracts from interviews recorded on each site were selected as representative of all responses in semi-guided interviews. This choice was verified on the basis of responses to the questionnaire. Therefore, they may be considered significant and representative of the manner in which the residents of a site perceive their district, their housing conditions, the road and the annoyance they suffer from the latter.

c. Analysis of responses to survey.

On the basis of all responses to the questionnaire and those gathered during the interviews, it was possible to draw certain conclusions, site by site. Chapter III of the forms will indicate the essential content of these conclusions. It was possible to elicit some of them in the establishment of the forms, when they concerned aspects of annoyance hardly occurring in the other sites studied.

II. RESULTS OF SURVEYS PER SITE

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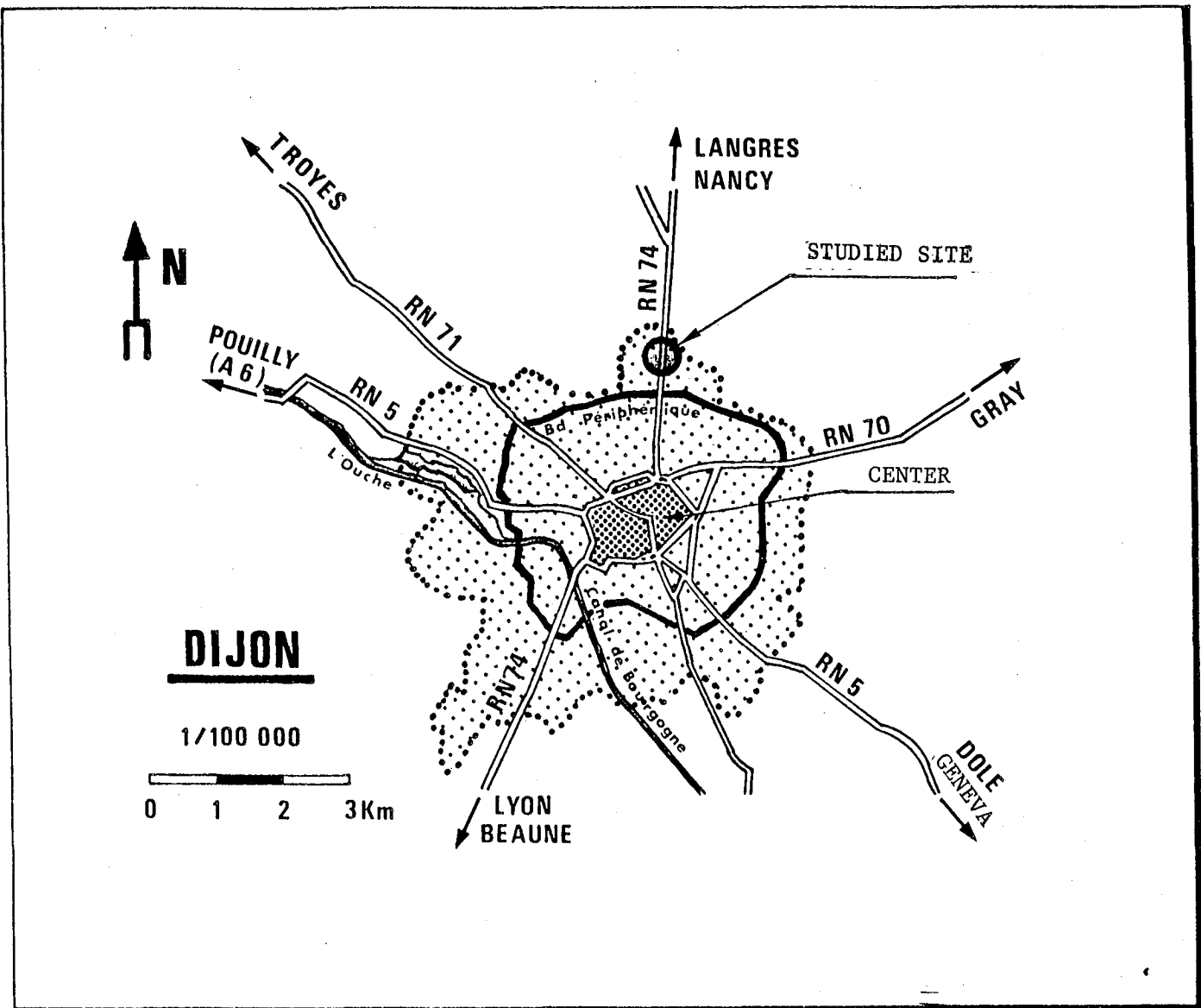
Results of the surveys are the object of a recapitulatory form for each of the 10 sites studied.

1. PRESENTATION OF THE EXAMPLE

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1.1. The Studied Site.

It consists of a group of apartment buildings of average height (three to seven stories) and a small area with villas (see Sketch No. 2.)



D I J O N 1

Former great penetration route, Avenue du Drapeau (RN 74).

This housing group is located in the northern periphery of the city of Dijon, not very far from the center (less than 2 km). It is part of a dense urban network.

The buildings were erected between 1960 and 1968. They are either side of the Avenue du Drapeau, at a distance of 20 to 40 m from the road. Generally speaking, the residences have double

exposure, i.e., one apartment gives onto a facade exposed to noise and onto a quiet facade of the building.

The residents are generally owners of their apartment (co-ownership system).

This district is very convenient with regard to public transportation. The facilities needed for everyday life are nearly all there: small commercial center, pharmacy, doctor, schools, institutions of secondary education.

1.2. The Road and the Traffic it Carries.

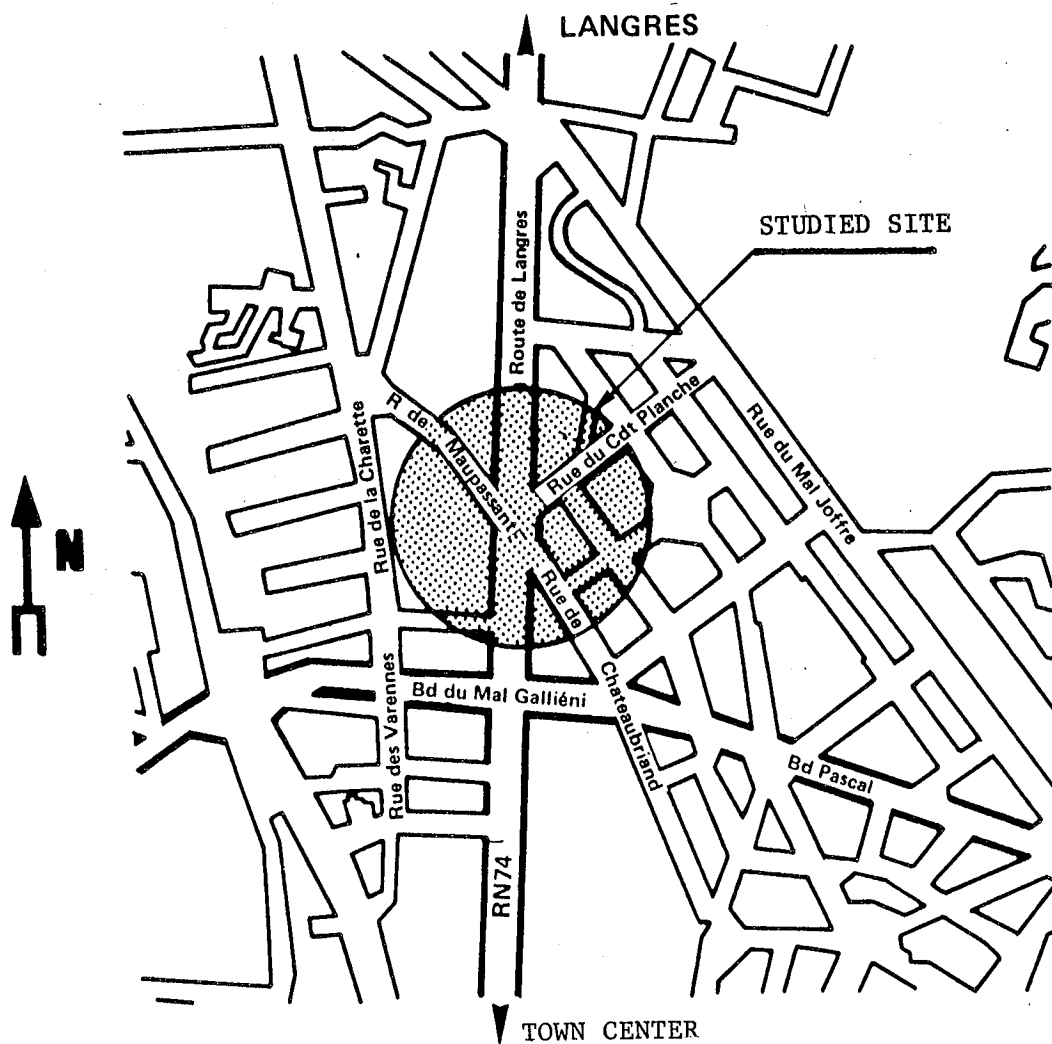
The studied site is crossed by RN74, which in this section is called Avenue du Drapeau.

This avenue has three traffic lanes and two pedestrian crossings. The first traffic lights are 200 m away from the site, in the direction leading toward the center of the city, at the intersection of RN74 and Pascal and Gallieni Boulevards.

A traditional urban highway, Avenue du Drapeau represents the main road of penetration toward Dijon for traffic coming from the north. Accordingly, it carries both urban traffic (periphery center connection) and transit traffic from Langre crossing the site and taking the peripheral route (Gallieni and Pascal Boulevards) to avoid the center of Dijon.

The traffic carried by this road has increased progressively during the last few years. The annual daily average was 13,500 vehicles a day in 1973, and the peak hourly traffic (at noon and between 6 and 7 p.m.) did not exceed 1,200 vehicles.

The proportion of trucks is between 10 and 20% during the day, varying between 20 and 60% at night (40% trucks at 100 vehicles/hour at 3 a.m.).



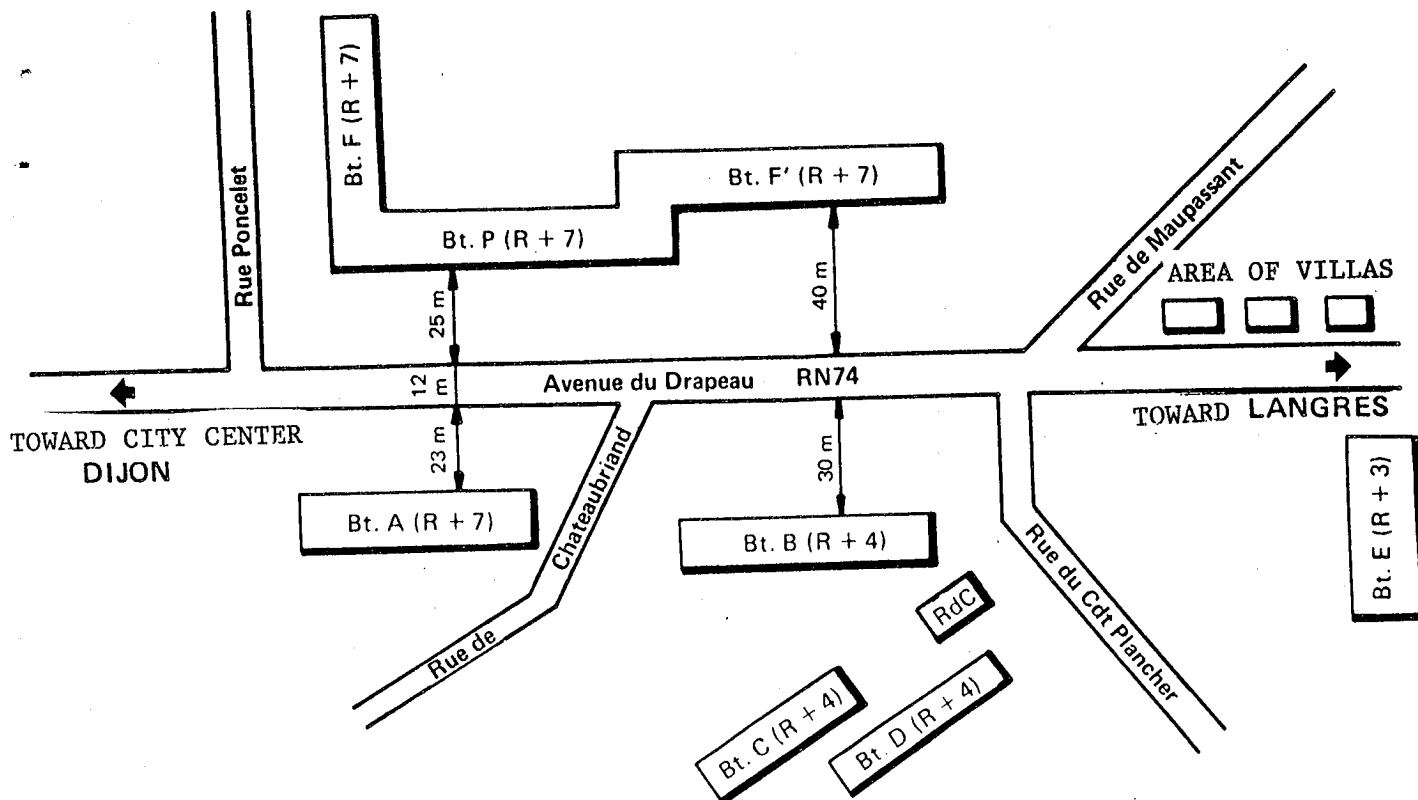
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SKETCH 1.

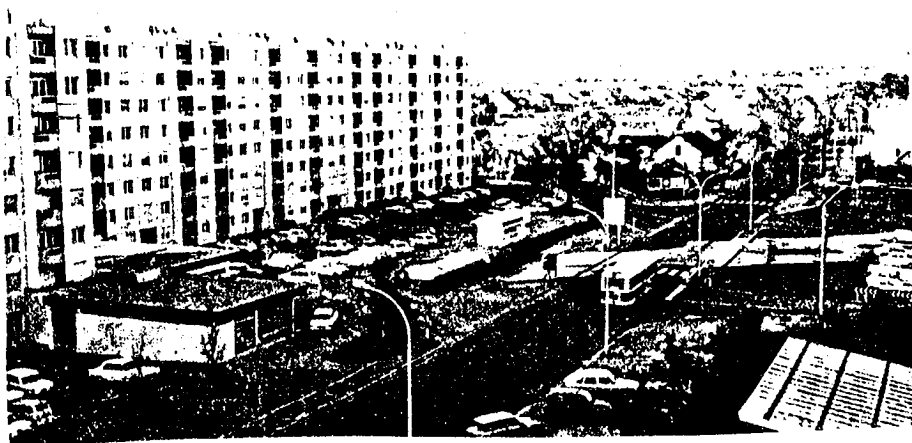
1.3. Noise Levels.

In the studied site, 80% of the people are exposed to a noise level higher than 69 dB (A). This figure represents as average sound level expressed in L_{eq} and measured 2 m from the bades of the buildings during a period extending from 8 a.m. to 8 p.m.

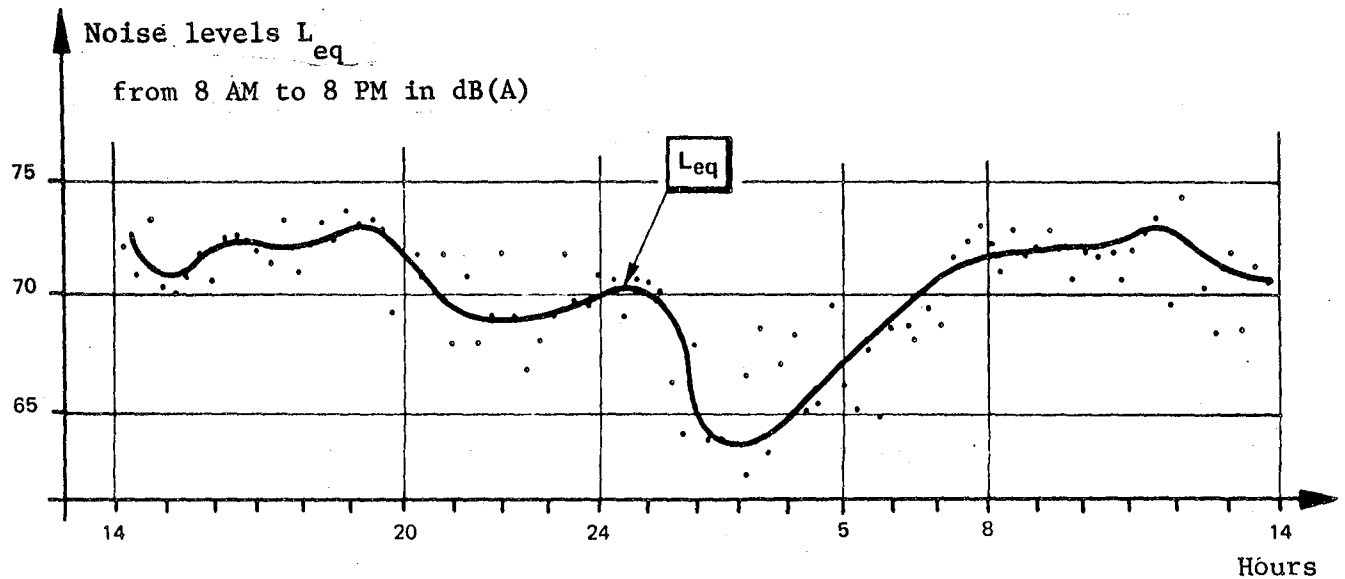
The most exposed facades of the site are exposed to noise levels reaching 74 dB (A).



SKETCH 2.

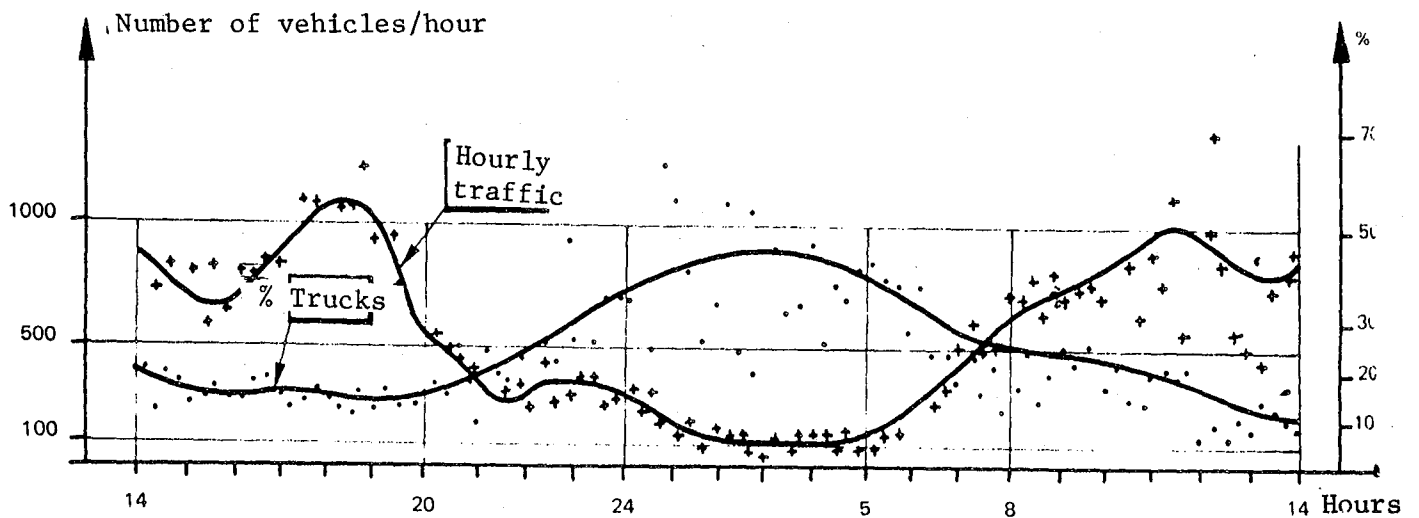


Avenue du Drapeau in the direction of Langres



SKETCH 3. Hourly variation of noise levels over 24 hours at a point in the site chosen arbitrarily.

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SKETCH 4. Traffic elements (counted on November 6, 1973.)

2. RESPONSES OF THE PEOPLE TO THE SURVEY

The survey conducted on this site made it possible to reveal the following results:

2.1. NOISE LEVELS AND CORRESPONDING ANNOYANCE OF RESIDENTS NEAR ROAD.

Average noise levels (L_{eq} , 8 a.m.-8 p.m.) In dB (A) on the most exposed facade of the building.	74	71	68	65	62	59
Number of persons questioned who were exposed to the cor- responding noise.	62	20	-	-	10	6
Responses most fre- quently given regarding annoy- ance ⁽¹⁾	Highly annoyed 60%	Highly annoyed 60%	-	-	Highly annoyed 40%	Hardly annoyed 50%

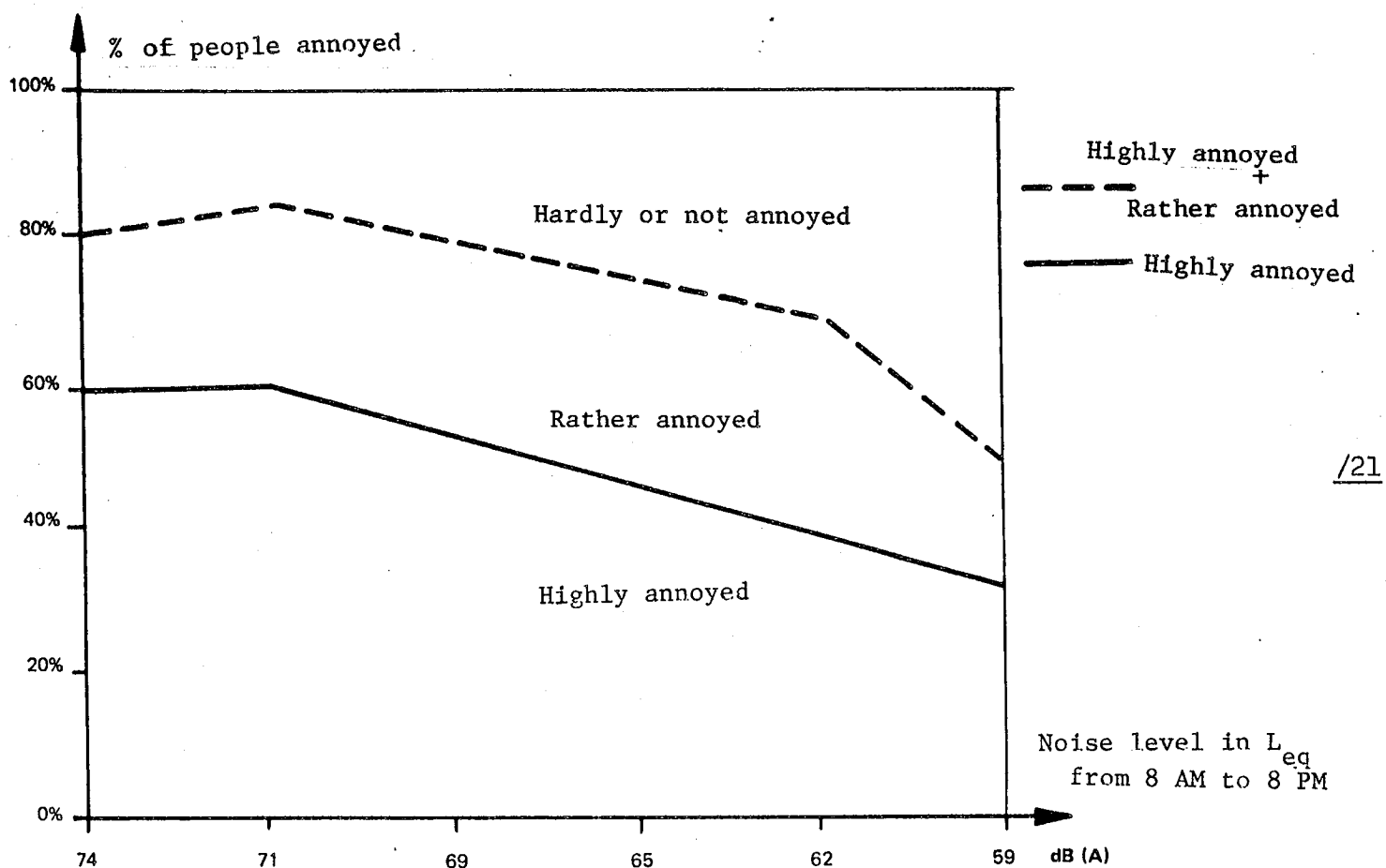
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⁽¹⁾ Responses were classified into four categories: highly annoyed, rather annoyed, hardly annoyed, not annoyed. In the table, the most frequent response is indicated for given sound level.

2.2. SIGNIFICANT EXTRACTS FROM INTERVIEWS WITH RESIDENTS NEAR ROAD /22

"As for me, I adore living with the windows open. When the weather is fine, I open all the windows, so you see it's a real handicap. It annoyed me here at first, you know, the business of having things shut except in the morning when cleaning house. If you have to raise your voice to be heard, you know, it's annoying."

"On the other hand, I noticed this summer that if you want to watch TV, you can't hear anything even if you have the windows and the shutters lowered."



SKETCH 5.

"I assure you that when you are in this room you hear everything, whereas on the other side you don't hear a thing. The park is not noisy at all, and you hear nothing. But on this side, it's not very pleasant, you know, eh!"

"It's those trucks, oh, yes! And the people I hear talking around me say the same thing!"

"I think if only there were something to divert especially heavy trucks, for example! In many cities, you see "Compulsory road for heavy duty trucks", so that none of them pass through residential areas. There should be an external road. I don't believe we should be forced to stand (the noise of heavy trucks), eh! Perhaps we are putting up with it because things are badly

organized. Badly arranged. There are measures to be taken if you like, which by the way could be taken."

3. ANALYSIS OF RESPONSES TO THE SURVEY

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3.1. District, Housing, Road.

District -- Satisfaction expressed by residents about the district is due to:

- fairly complete facilities (schools, businesses, etc.);
- closeness to center of town;
- facilities to reach center of town, either by private car or public transportation, through the Avenue du Drapeau.

Housing -- The quality of the housing is assessed as good. The presence of such related amenities as an internal park designed for leisure activities is really appreciated.

Road -- Residential buildings were set along the Avenue du Drapeau little by little. Just as in those villages that extend in length only, on either side of a highway, the essential characteristic of this district is that it was established along an important highway. The road is a reality which is taken into account in the district.

Crosswalks are considered to be sufficient, and pedestrian safety does not seem to pose a problem.

3.2. Annoyance and Noise.

Observation of the data on annoyance and noise (see Sketch No. 5) shows that a change in the attitude of residents near the

road occurs with a noise level (L_{eq} from 8 a.m. to 8 p.m. at the facade of the building) of about 59 to 62 dB (A). Forty per cent of the persons exposed to a noise level of 62 dB (A) declare that they are highly annoyed. But even at 59 dB (A), which is a low level, the annoyance exists. This may be due to the rural origins of some of the people, who enjoy living with their windows open.

-- The predominant elements of annoyance are related to the percentage of heavy-duty trucks and the presence of a crossroad with traffic lights 200 m away from the site:

- The crossroad entails starting and braking, often considered very disturbing.
- The noise of heavy-duty trucks represents the major problem. Whereas it is 1 PL - 9 VL in the acoustic level, a heavy-duty truck is felt to be 14 times more annoying than a light vehicle.

-- The solutions expressed most often by persons questioned, to do away with this annoyance, consist in:

- Internal arrangement of the apartment: double exposure allows them to choose the quiet rooms for rest (bedrooms) or living room. These arrangements were, indeed, used effectively by building residents.
- Possibility of deviating traffic of heavy-duty trucks before they enter town, at least at night.

III. ELEMENTS OF SYNTHESIS

Elements of synthesis were grouped under seven headings.

1. Characteristics of the Sampling of People Surveyed.

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For all 10 sites, the sampling studies concern 980 persons.

Taken as a whole, i.e., combining all the sites, the various characteristics of this sampling are often close to the characteristics of the national population.

The male-female distribution, the socio-professional categories (CSP), the status of occupancy of the residences and the rate of occupation of the rooms are comparable to national data.

Only two special characteristics are revealed:

- The population of the sampling is younger than the national average. There is under-representation of older persons (over 60).
- We have a high proportion of middle-level professions near roads studied. For other categories, the sampling is comparable to national data.

2. Views on the Road of the Residents Living Nearby.

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On the whole, the opinions on the expressway regarding access and convenience are fairly favorable.

The usefulness of VRU (urban expressways) is considered slight for everyday life. That of mixed highways⁽¹⁾ is considered good for shopping and leisure activities. The traditional roads are the ones most used by persons living near them.

⁽¹⁾ See definition on page 5 of this document.

It is acknowledged that highways offer considerable advantages with respect to the speed of travel, wide-spaced and pleasant nature of the landscape, and, to a lesser degree, the safety of the automobile. But the use of this type of road is considered tiring. It is felt that it makes a considerable break in the district.

Pedestrian safety is considered poor for traditional and mixed roads, since it is possible but not very safe to cross. Crossing expressways is less dangerous, which explains the positive opinion on pedestrian safety.

A comparison of these opinions with the criteria of fluidity, safety and comfort sought by road engineers is interesting. Fluidity and safety are considered good for expressways. Convenience of use is considered inadequate for the communities living along these expressways.

These results are summarized in the table on a following page. A favorable opinion is indicated by a score of 3, an unfavorable opinion by 0, an intermediate opinion by the scores of 2 or 1.

3. Contribution of Various Noise Sources.

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3.1. Annoyance Due to Traffic Noise and Other Noises.

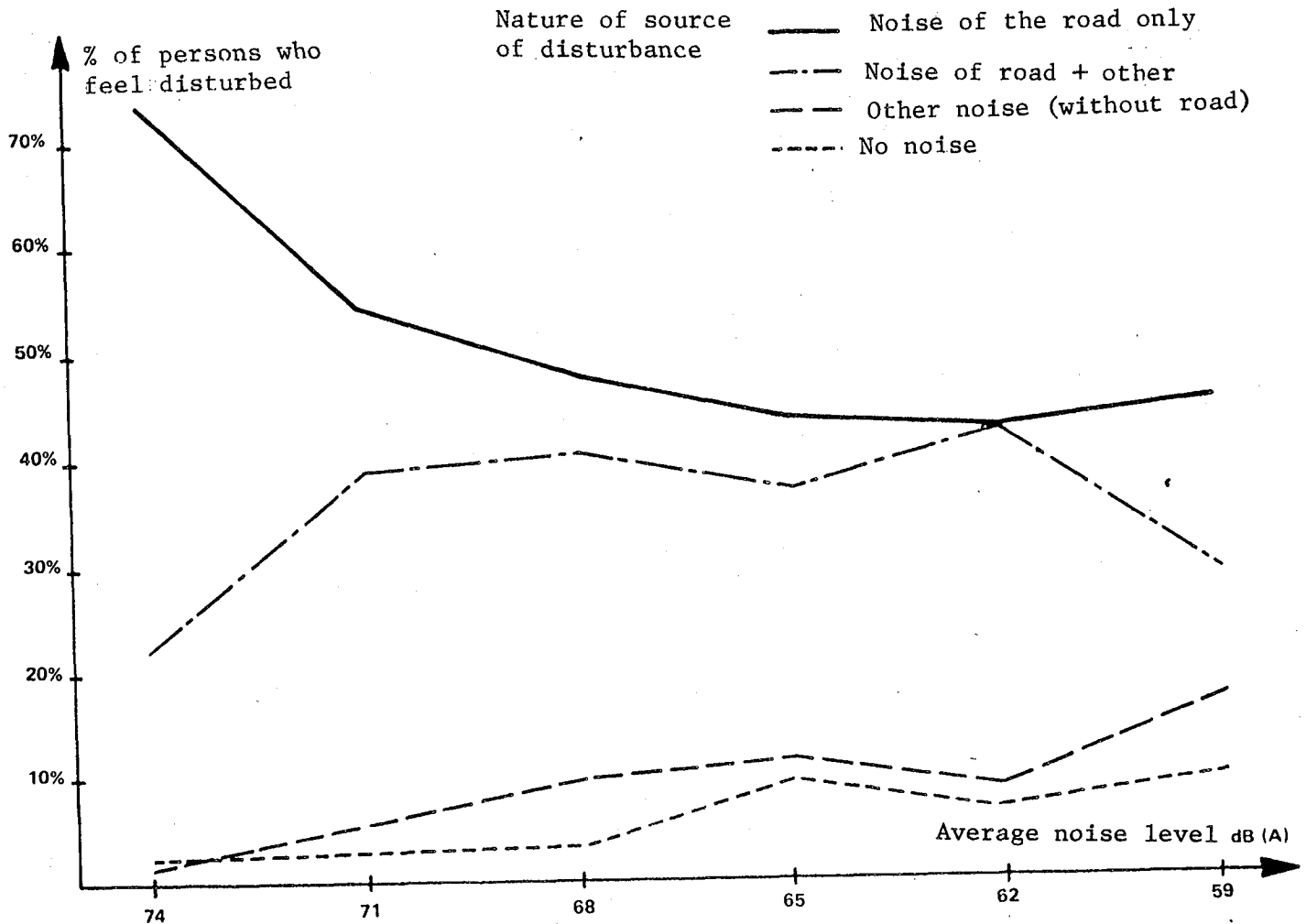
On the 10 sites, we estimated contributions of traffic on roads considered and of other sources to noise perceived by persons living near the roads.

Of the 980 persons questioned:

- 50.8% feel that they are annoyed mainly by the road in question;

- 7.6% feel they they are annoyed by other noises (neighborhood, etc.) and not by the road;
- 36.3% consider they they are annoyed by both the road and other noises;
- 4.4% feel that they are not annoyed by any noise.

These responses are distributed as follows as a function of the sound levels to which the persons questioned were actually exposed:



	Expressways (300 persons)	Mixed Roads (300 persons)	Traditional Roads (300 persons)	
Easy access ⁽¹⁾	3	2	3	
Close access ⁽¹⁾	3	3	3	
Convenient access	3	2	3	
Usefulness for work ⁽²⁾	0	1	3	
Usefulness for leisure activities ⁽²⁾	0	3	3	
Usefulness for shopping ⁽²⁾	0	3	3	
Rapid traveling ⁽¹⁾	3	2	2	
Esthetic appearance	2	2	2	
Cleanliness	3	2	2	
Spacing	3	2	2	<u>/105</u>
Attractive landscape	3	2	2	
Safety for cars	2	2	2	
Safety for pedestrians	3	0	0	
Uniformity of the district	0	1	2	
Pedestrian crossing	3	0	1	
Crossing by car	3	2	1	
Restful use	0	2	2	
Modern use	3	2	0	
Frequency of use ⁽²⁾	0	3	3	

REMARK: Certain criteria (1) are apparently opposite to other criteria (2). Actually, the table should be read as follows: the expressways are rated by the residents nearby as used very infrequently and, therefore, of little use. But when these residents use these expressways, they acknowledge that their access is easier than traditional roads, and that traveling on them is faster.

It may be seen that among people exposed to a sound level /107 of 71 dB (A), for example, 54% feel that they are annoyed by the noise of the road only; 39% by the road and other noises; 5% by noises other than those caused by the road; and 2% no annoyance from noise.

Whatever the noise level, traffic noise is always pre-dominant, alone or combined with other noises (noises inside or outside the residences, neighbors, children, etc.) When traffic noise decreases, the perception of other noises increases greatly. When the noise level is about 59 dB (A), the residents are better able to distinguish between the noises. The neighborhood noises then become more significant and, therefore, quite as disturbing.

3.2. Most Annoying Types of Vehicles.

In the flow of traffic traveling on the expressway, all vehicles are not considered equally annoying. When different types of vehicles are classified as a function of the annoyance they cause persons living near the roads, the following order is found:

heavy trucks > motorcycles > mopeds > light cars

This order should be reduced to heavy trucks > motorcycles > automobiles, since there are few mopeds on expressways. But they are considered as more annoying than would have been expected from noise levels emitted. This is because of the emission of more acute frequencies, maximum use of speeds and frequent suppression of silencers in this type of vehicle.

The heavy-duty trucks are often mentioned as noisiest and most annoying. For each site, we calculated the "acoustic equivalence" and the "annoyance equivalence" between a heavy-duty truck and an automobile (for more details on these equivalencies, please refer to the Appendix on page 123 of this document).

It was observed for all the sites that a heavy-duty truck is acoustically equivalent to four to twelve automobiles. On the other hand, it was found that the perceived equivalence of the truck may reach that of ten to twenty cars.

4. Variation of Noise Levels in Different Sites Over 24 Hours /108

For each site, the indication of the variation of noise levels L_{eq} over 24 hours at an arbitrarily chosen point in the site was given, and, for comparison, the variation of the overall traffic (VL + PL) and that of the percentage of heavy trucks (see the forms per site).

On the basis of this indication (obtained by measurements) and to compare different sites with each other, L_{eq} was calculated hour by hour at a point 30 m away from the road, for each of the sites.

It may be seen that for most of the sites (see forms per site), the hourly variation of the L_{eq} (calculated for 30 m distance from the road side) may be divided into four periods:

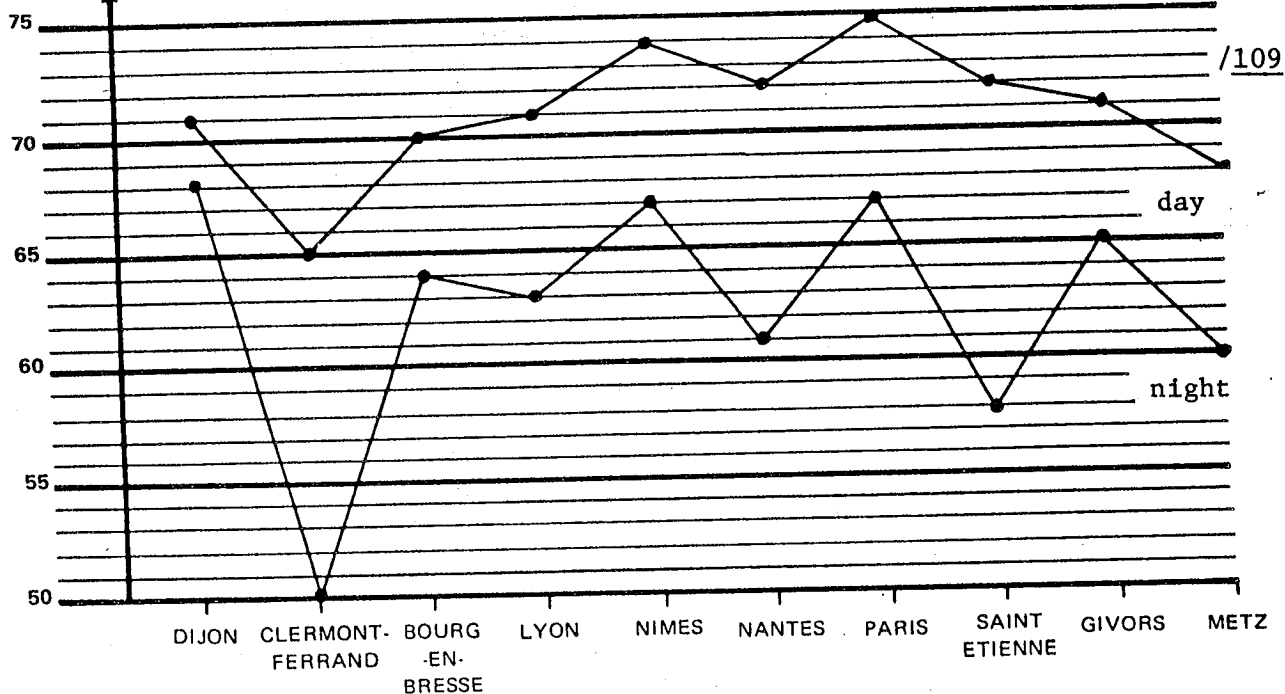
Daytime (8 a.m. to 8 p.m.) -- The level is approximately constant. During this period, since decreases in numbers are compensated for by increases in speed, peak hours are only slightly noisier than others.

At the time of going to sleep (8 p.m. to midnight) -- The L_{eq} level drops slowly to the minimum (reached between 2 a.m. and 3 a.m.). This decrease is sometimes disturbed at the time a show is over.

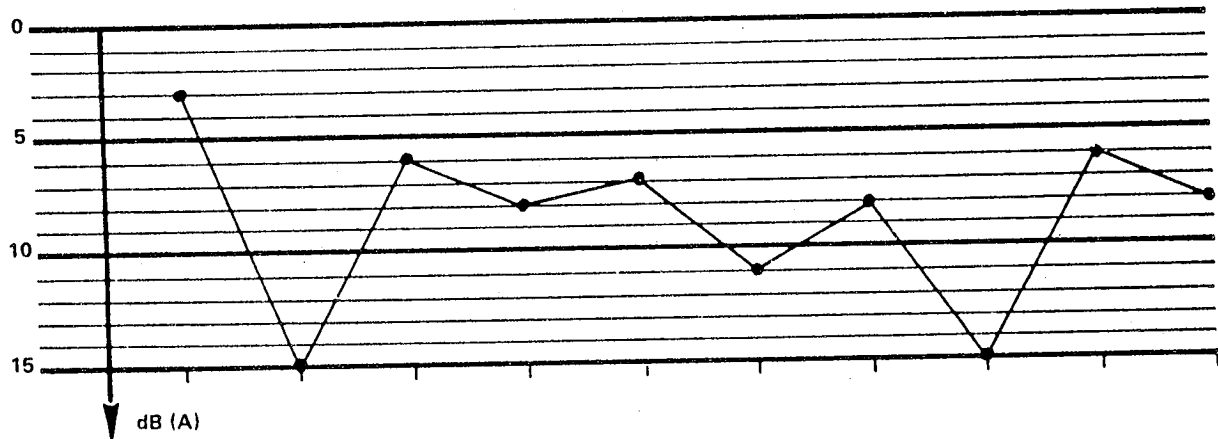
During sleep (midnight to 5 a.m.) -- The night time slacking off is more or less great, depending on the sites. This decrease is noticeable particularly in the sites where there are few heavy trucks at night (see table on following page.)

At time of waking (5 a.m. to 8 a.m.) -- From 4 a.m., the noise level increased fairly rapidly until 8 a.m., when values complare or are slightly lower than at daytime levels.

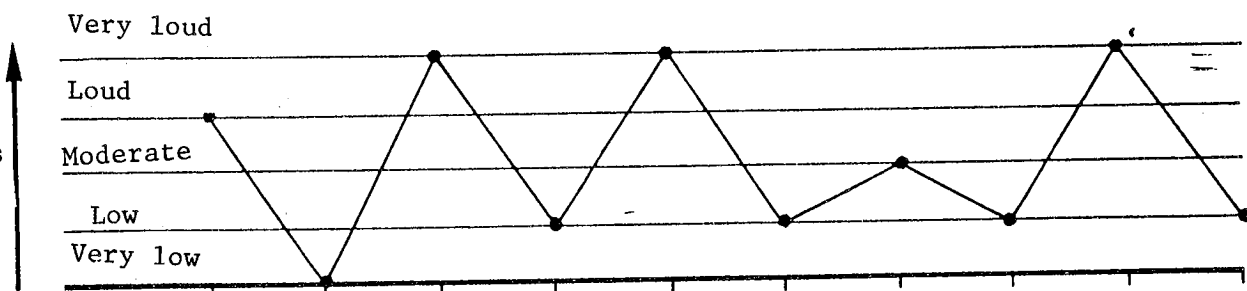
$L_{eq} \text{ in dB (A)}$



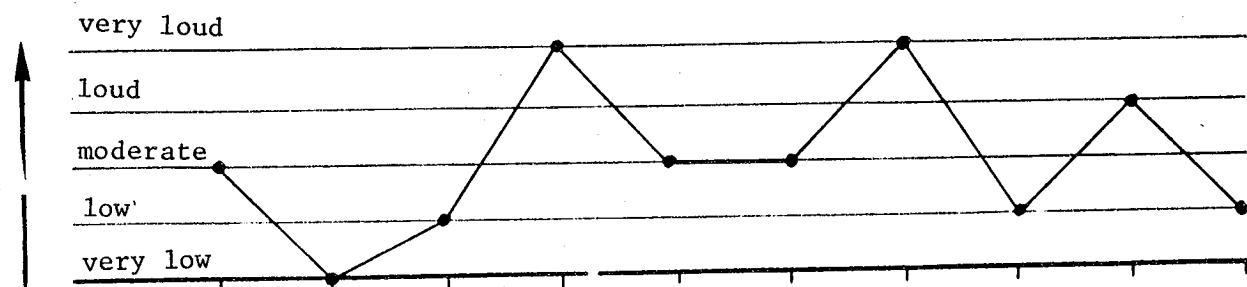
Nighttime increase
(Difference between L_{eq} daytime and L_{eq} at night)



% of trucks at night



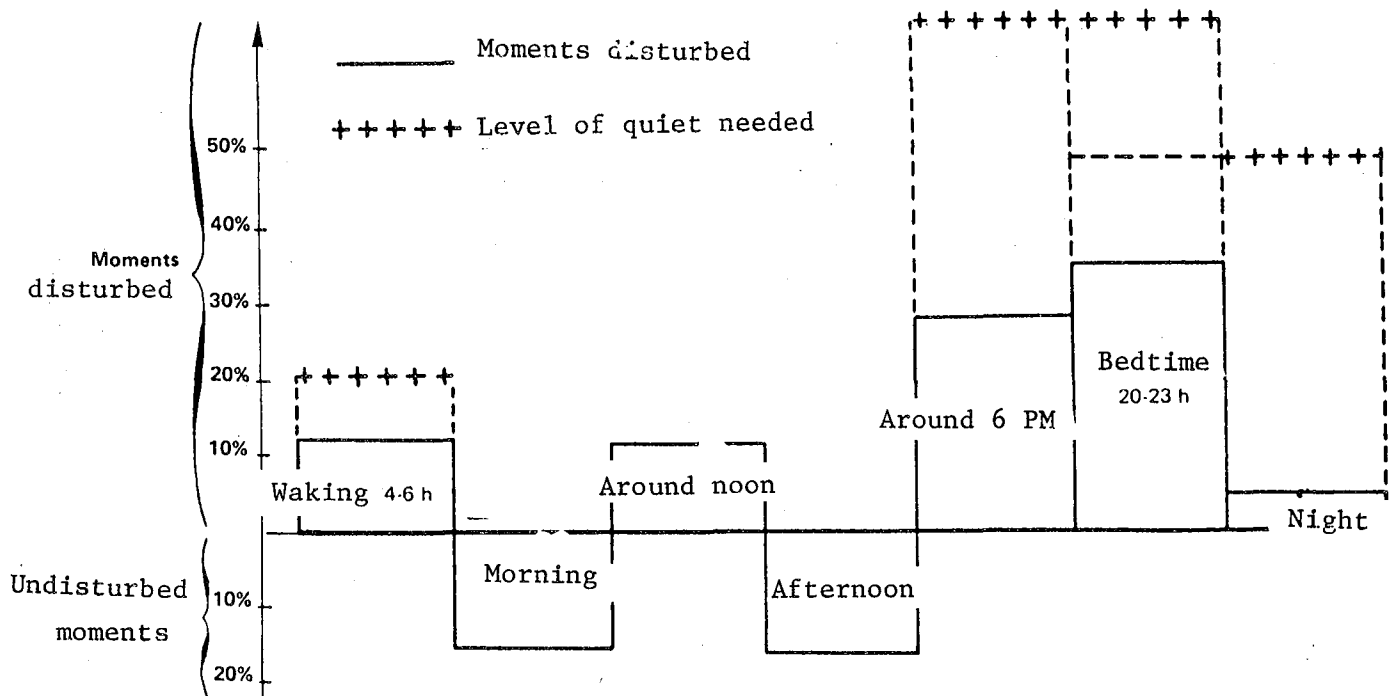
Night traffic



The previous studies described the annoyance by activities affected. One of the major results of the study of the CSTB⁽¹⁾ had been to distinguish clearly between daytime and nighttime annoyance. This survey made it possible to better assess the annoyance at different times of the day.

5.1. Times Disturbed.

Difference between the percentage of persons disturbed and persons not disturbed over the different times of the day:



The above graph represents the responses of persons near the road with respect to annoyance felt at different times

(1) Aubree-Auzou-Rapin: "Study of the Annoyance Caused by Urban Traffic," June, 1973.

of day. For instance, the time of waking (4 a.m. to 6 a.m.) is considered as a disturbed period by the persons interviewed. The level reached represents the difference between persons who consider that time as disturbed (16%) and those who do not consider it disturbed (4%). On the other hand, the morning is considered as an "undisturbed period".

The ++++ line represents the level of need for quiet. For a given period, this level is proportional to the number of persons who asked for protection. For instance, the noon period aroused no call for protection. On the other hand, the periods of 6 p.m. and at bedtime (8 p.m. to 11 p.m.) were the object of many requests at the time of the survey.

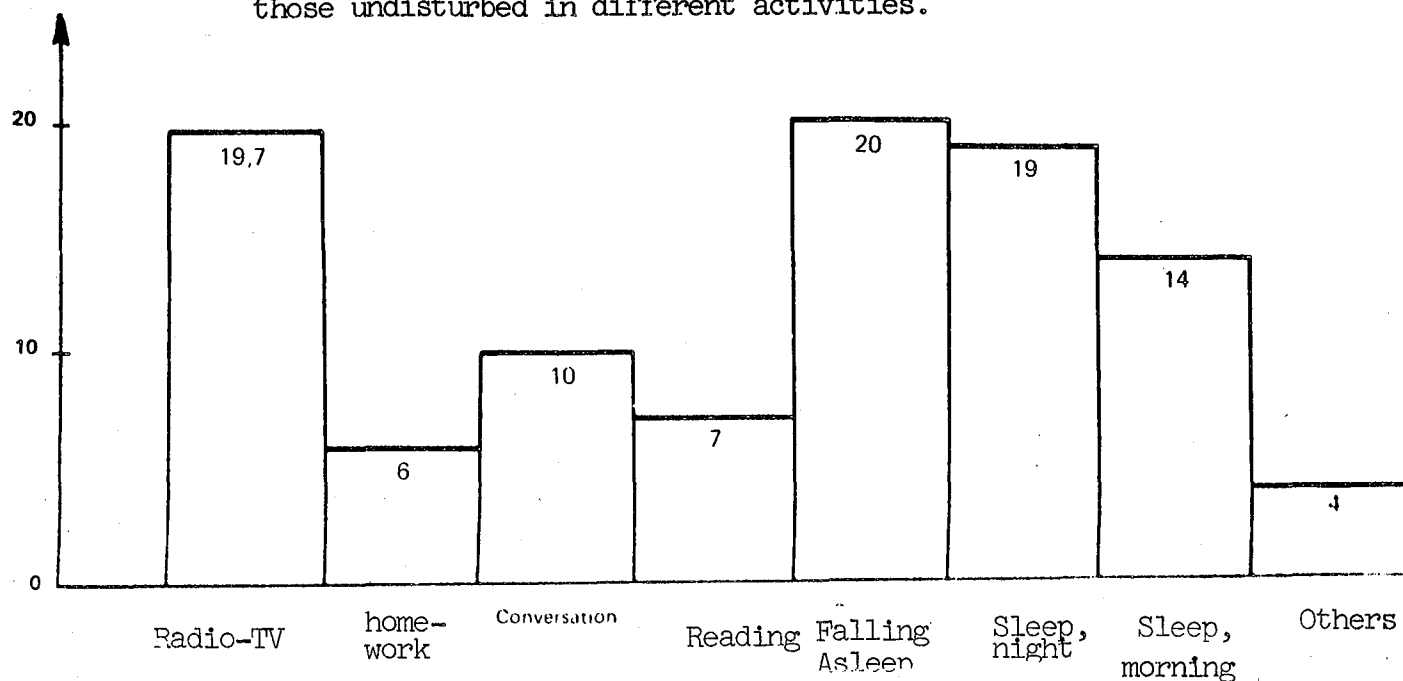
Generally speaking, the reading of the above graph shows /111 that the most disturbed times are early evening and overnight. Those who reside near the road seem hardly to be disturbed in the afternoons and mornings. This is actually the manifestation of a state of balance between certain sites which are not affected at night (Saint Etienne and Clermont-Ferrand) and other more disturbed (Nimes and Givors).

5.2. Activities Disturbed.

=
The following table shows responses to the survey.

Activities disturbed are basically connected with night rest and radio/TV listening, which correspond to evening and night. We observe satisfactory consistency between responses concerning disturbed periods and those concerning disturbed activities.

Difference between percentage of persons disturbed and those undisturbed in different activities.



6. Noise Level and Annoyance.

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6.1. Annoyance and Acoustic Indicators/Correlations.

Many indicators may be used to describe the acoustic situation of sites located along traffic roads over a given period of time.

- Indicators derived from statistical analysis of noise levels:

L_1 , L_{10} , L_{90} , over period studied.

- An indicator connected to acoustic energy emitted by the source:

L_{eq} over period studied (see Remark, page 10 for the definition of L_{eq}).

- Any other complex indicator: L_{st} (Federal German); LNP, TNI (Great Britain); all combinations of the aforementioned indicators:

L_{50} and standard deviation σ , or L_{50} and L_1 and L_{10} .

Although slight, the best correlations between overall annoyance (over 24 hours) and the physical indicators calculated for different periods of the day were as follows:

- Annoyance⁽¹⁾ x noise expressed in:

L_{eq} from 8 a.m. to 8 p.m., $\rho = 0.31$
 L_1 from 8 p.m. to midnight, $\rho = 0.35$
 L_{eq} from 8 p.m. to midnight, $\rho = 0.3$
 LNP from 8 p.m. to midnight, $\rho = 0.35$

ρ : Spearman correlation coefficient, established on individual answers.

L_1 : Level reached or exceeded for 1% of the time.

LNP : Level of Noise Pollution = $L_{eq} + 2.56 \sigma$

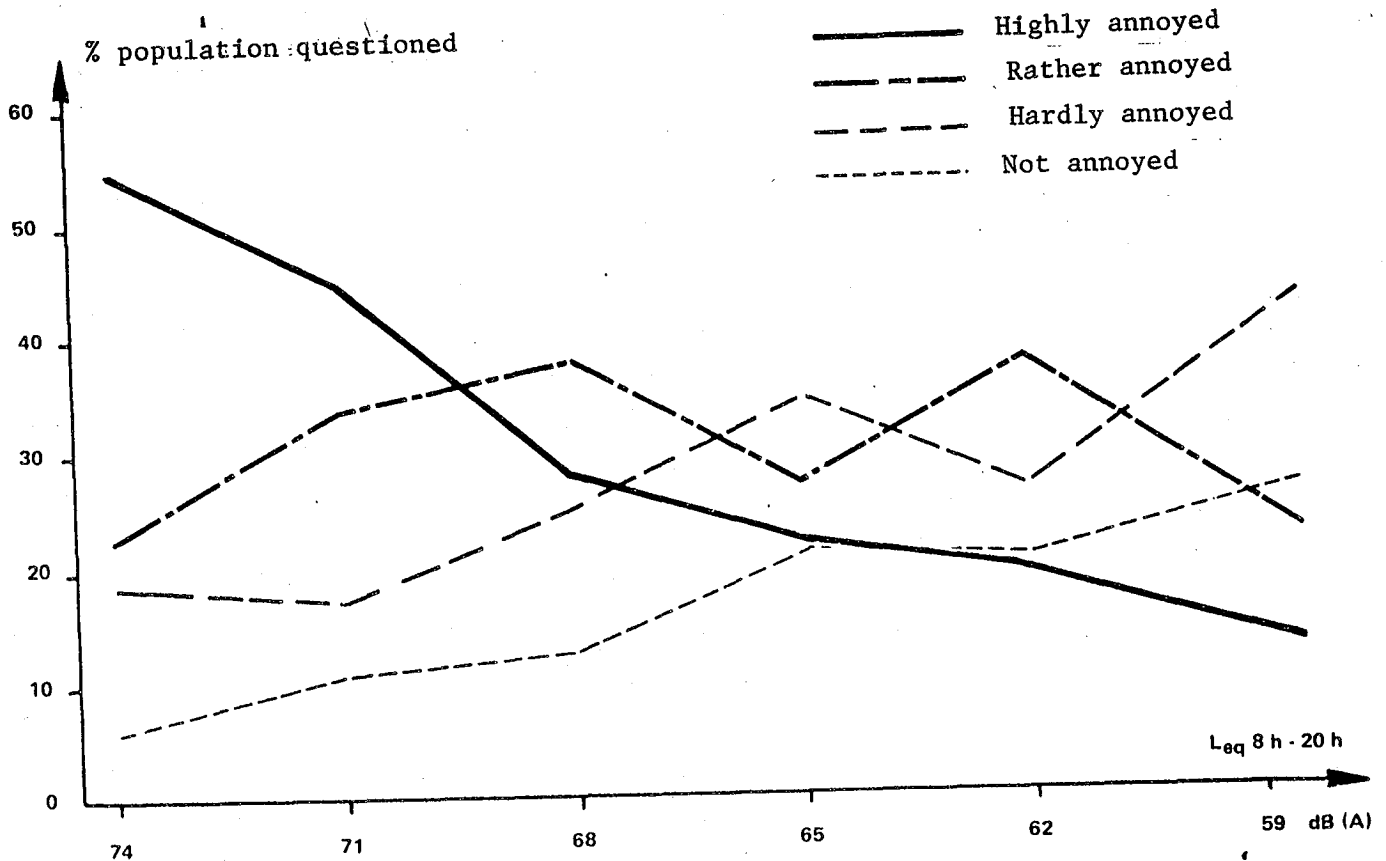
The results obtained are comparable to those of the other large surveys (CSTB Study, 1971; English BRS study, 1968).

6.2. Annoyance of Residents Near Roads.

Persons interviewed could choose between four possible responses: highly annoyed, rather annoyed, slightly annoyed, not annoyed.

(1) Annoyance conserved here is overall annoyance of roadside residents for all periods of the day.

The following graph gives the responses of all persons questioned in the 10 sites (980 persons) as a function of the noise level to which they were exposed, expressed with the indicator L_{eq} , 8 a.m. to 8 p.m.



7. Modulation Factors of Annoyance Other Than Noise

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During previous surveys, it appeared that many factors other than noise influenced the annoyance/noise correlation. One of the most obvious factors is an individual sensitivity of the residents near roads, a sensitivity which varies greatly from one subject to another. Annoyance is also affected by many other factors.

Among them, five factors whose effect was significantly

observed during the present survey were:

- Type of housing and status of occupation of the residents;
- Rate of exposure of the residences;
- Configuration of the road;
- Use of the road;
- Work site (on the spot or outside the site).

It is possible to define factors other than those mentioned. They are not excluded categorically, a priori, but they simply did not appear to affect the annoyance/noise correlation significantly in the present study.

The manner in which these five factors modulate the annoyance/noise correlation is analyzed below. Since the acoustic measurements show a wide spread, however, the conclusions relating to each factor can only be considered as indications of a trend.

7.1. Modulation as a Function and the Status of Occupation of the Residents

Residents of villas (generally the owners) are among the most critical with respect to noise. This corresponds to the requirement for quiet inside the apartments but also in the surroundings of the residence (enjoyment of the gardens). But we note that certain residents of villas, although they are exposed to high noise levels, have a clear tendency to rationalize a situation which they know will have to be tolerated for a long time (Givors, Metz) since they are long-term residents.

Status of occupation has a considerable effect on residents of apartment buildings.

Owners who consider their residence as capital depreciating in value are much more critical with respect to a noisy environment.

Renters are less aggressive with respect to the problem of noise. This is all the more true in dealing with persons who often have many other urgent problems to solve.

7.2. Modulation According to the Exposure Rate of the Residence. /115

For low sound levels, annoyance is lower when the exposure rates are low (4/10 of the windows facing the road). If the exposure rates are high (8 to 10/10 of the windows facing the road), the annoyance is greater, confirming the results of CSTB investigations of 1967 and 1971 previously mentioned.

Starting from 65 dB (A) in L_{eq} , the effect of the exposure rate disappears.

7.3. Modulation According to the Configuration of the Road.

It seems that many characteristics of the site or traffic are associated with the configuration of the road.

However, it may be noted that there is no significant difference between expressways and mixed roads.

On the other hand, the configuration of traditional roads with pulsed traffic, sometimes related to a U-shaped geometric, is clearly the source of greater annoyance than the other configuration at the same noise level.

7.4. Modulation According to Use of the Road.

At low noise levels, we observe coincidence between persons who make little use of the road and a very moderate expression of annoyance. This phenomenon is due to the fact that communities which are not used to this type of infrastructure do not center

their conversation on the topic spontaneously.

7.5. Modulation According to the Place of Work.

This study revealed no simple correlation between the classification in any given socio-professional category and the annoyance (whatever its nature or intensity) felt by the residents along the roads considered.

The only significant distinction it was possible to establish concerns, on one hand, the persons remaining on the spot (housewives, non-working population, etc.) and persons working away from the site.

On the other hand, it is observed that the annoyance/noise correlation is better for the "non-working population + housewives" sampling, i.e. the persons remaining at home, than for the total sampling.

On the basis of the study of traffic and conditions of propagation, the present or future acoustic situation of a site may be defined.

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The knowledge of the acoustic situation gives us an idea of the annoyance suffered by the residents. But since the correlation of the annoyance/noise relation is slight, it must be modulated by annoyance factors other than noise.

The knowledge of elements of a site concerning each of the five previous factors permits us, therefore, to specify annoyance of site residents further in a qualitative manner.

IV. GENERAL CONCLUSIONS

The IRT study, summarized in this document, makes it

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possible to describe the main aspects of annoyance caused by a beltway through studies concerning a sampling of 10 sites with the most varying characteristics.

Given site by site, the results contained in part II of this document furnish a statistically-based testimony on the manner in which persons living along large expressways react to noise caused by the road.

The elements of the synthesis given in part III allow general indications to be derived on the image of the road, the sources of annoyance, the times of disturbance, the activities interfered with and the way in which certain factors other than noise modulate the annoyance. The main results are as follows:

1. Image of the Road.

Noise is a predominant element in the annoyance, but to this element we must add the assessment of the road by a nearby resident (comp. Chapter II of part III of this document.) The attitude of the resident living near the road is a function of the characteristics of the road appropriate or not to the use he or she would like to make of it. The road-building engineer, therefore, will have to know whether the type of road (traditional, mixed or expressway) has geometrical characteristics (access, crossing) adequate to satisfy the expectations of residents living nearby, in order to understand their attitude.

2. Perception of Different Sources of Noise.

Road traffic represents the predominant source of noise around expressways.

In the flow of vehicles, the sources are mentioned in the following order of annoyance:

truck > motorcycle > moped > car

Trucks are often mentioned as the noisiest and most annoying. In the different sites, a truck is as noisy as four to 12 automobiles. Meanwhile, the perceptual equivalence of a heavy truck may reach 10 to 12 automobiles in certain sites.

In the case of pulsed traffic (Dijon, Bourg-en-Bresse, Nimes), the annoyance caused by heavy trucks is clearly greater than in the case of continuous traffic (Paris, Metz, Saint Etienne).

3. Times and Activities Disturbed.

The survey shows that traffic noise disturbs nearby residents in the early evening especially. This period includes the traffic peak (6 a.m. to 7 p.m.) and corresponds to the evening's rest, listening to radio or watching TV and to bedtime. Sleep in the middle of the night does not seem to be much disturbed except in the sites where the nighttime traffic remains high, and especially when the percentage of heavy trucks becomes considerable.

4. Indicators Allowing Characterization of Noise Situation.

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One of the major conclusions of this study consists of the definition of the most suitable indicators to describe the noise situation of a given site.

This indicator should be easily measurable and easily forecastable. It should, of course, be correlated as well as possible with the annoyance felt by the users.

To characterize the annoyance caused by noise (combining all periods of the day) suffered by communities living near roads, either one of the following indicators could be used:

- L_{eq} calculated or measured during the period of 8 a.m. to 8 p.m.;

-- L_{eq} calculated or measured during the period of 8 p.m. to midnight;

-- L_1 measured during the period of 8 p.m. to midnight.

We refer here to the result of the study by the IRT. The indicators which must be used to characterize a given acoustic situation and to assess the extent of the annoyance are defined in the Chapter 0: "General Methodology" of the new Guide to Noise.

5. Annoyance Suffered by Residents Near Roads.

By grouping together the responses of all persons questioned in the 10 sites, we may indicate the percentage of persons annoyed for a given noise level (expressed in L_{eq} from 8 a.m. to 8 p.m.). This result is shown in the graph of page 113.

Generally speaking, the following conclusions may be drawn from the whole study and, in particular, from the analysis of the graph:

Below 60 dB (A) (expressed in L_{eq} from 8 a.m. to 8 p.m. in the facade area of the buildings surveyed), the noise caused by traffic may be considered as hardly or not at all disturbing, except in the special cases of sites or activities particularly sensitive to noise.

Above 68 dB (A) (L_{eq} from 8 a.m. to 8 p.m. in the facade area), the noise caused by traffic will be considered as annoying to the residents, except for special cases of sites (soundproof buildings, etc.) or activities not very sensitive to noise.

Between these two threshold values, the assessment of annoyance must take into account factors other than noise.

6. Factors of Variation of Annoyance.

The annoyance/noise correlation has a significant correlation coefficient but remains relatively low, nevertheless.

To arrive at the assessment of the annoyance, therefore, we will have to examine, besides the noise/annoyance correlation, various factors aside from noise which modulate the correlation.

Among all the factors, personal or relating to situation and lifestyle, the survey revealed five factors whose effect is significant:

-- The type of housing and status of occupation of the residents.

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-- Rate of noise exposure of the residence.

(These two factors express satisfaction with respect to the district and the residence.)

-- Configuration of the road (for equal noise level L_{eq} , the annoyance is greater for a traditional road than for an expressway).

-- Place of work (in the site or outside it).

The choice of these factors is not exhaustive. It is possible that on other sites, other factors may appear to have equal effect on the annoyance/noise correlation.

The conclusions relating to the modulation factors of the annoyance/noise correlation represent trend indications rather

than assessments transferrable directly to all cases encountered, in view of the spread of noise levels. The difficulty in arriving at clear conclusions in this area confirms -- if this had been necessary -- the complexity of this problem with multiple parameters, whose study is essential to permit a correct definition of the annoyance of those who reside near roads.

A P P E N D I X

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EQUIVALENCE BETWEEN AUTOMOBILES AND HEAVY TRUCKS UNDER THE ACOUSTIC AND ANNOYANCE ASPECTS

a. ACOUSTIC EQUIVALENCE

The hourly rate Q expressed in vehicles/hour is the sum of that of light vehicles Q_{VL} and heavy trucks Q_{PL} . If p is the percentage of heavy trucks, we write:

$$Q_{PL} = pQ \text{ and } Q_{VL} = (1 - p)Q$$

The light vehicles alone would produce a noise level L_o given by the formula:

$$L_o = 10 \log (Q_{VL}) + k \quad (1)$$

The actual measured noise level L is produced by the total traffic $Q = Q_{VL} + Q_{PL}$. It is connected with the rates Q_{VL} and Q_{PL} by a relationship of the type:

$$L = 10 \log (Q_{VL} + \epsilon Q_{PL}) + k \quad (2)$$

If we call ϵ the acoustic equivalence between a PL and VL, ϵ is calculated by substituting Q_{VL} and Q_{PL} in formulae (1) and (2) with pQ and $(1 - p)Q$. We derive from these two equations with two unknowns:

$$L - L_0 = 10 \log \left(1 + \frac{\epsilon p}{1 - p} \right)$$

therefore:

$$\epsilon = \frac{1 - p}{p} \left(10^{\frac{L - L_0}{10}} - 1 \right)$$

b. EQUIVALENCE FROM POINT OF VIEW OF ANNOYANCE

We have just defined a coefficient of "acoustic equivalence" such that $1PL = \epsilon VL$. In the same manner, we may define an "annoyance equivalence" such that $1PL = \alpha VL$.

The basic data to calculate this coefficient of annoyance equivalence came from the psycho-sociological surveys carried out on the 10 sites studied and, particularly, from the responses to questions concerning the noisiest types of vehicles, on one hand, and overall annoyance on the other.

One question concerned the more or less noisy nature of different categories of vehicles. The person questioned had to classify the four following types of vehicles by order of increasing annoyance: automobile, moped, motorcycle, heavy truck.

By arbitrarily assigning each type of vehicle a "score", which is a function of its rank in the above-mentioned classification, we can obtain an average per side for all persons interviewed. If we compare the average of "annoyance caused by cars"

to that of "annoyance caused by heavy trucks", we may derive the value of the coefficient of equivalence α .

To know whether the "scores" chosen to characterize the /124 annoyance are good, we calculate $L'_{eq} = 0 \log (Q_{VL} + \alpha Q_{PL}) + k'$. By putting forward different hypotheses for the score of ranks of annoyance of the vehicle types (i.e., using different metrics), several values are found for the coefficient α . The one giving the best correlation between L'_{eq} calculated in this manner and the overall annoyance expressed by the persons residing near roads is taken as the representative one.

* * * * *

The study summarized in this document was conducted at /125 the request of the Equipment Ministry, DRCR, in 1973, by the Center of Evaluation and Research on Nuisances (CERN) of the IRT (Transportation Research Institute).

The following persons took part in the study, under the direction of C. Lamure, Director of CERN:

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M. Maurin (Acoustics Engineer)
V. Blanchet (Technician)
J. C. Bryere (Technician)

with the collaboration of:

Informatics Research Center of the IRT
CETE Bordeaux
CSTB Nantes
Regional Laboratory of the Angrs Civil Engineering Dept.

This document represents a synthesis of the results of the IRT study to be used by all the Equipment Services facing noise problems along urban roads. It was planned and drawn up by:

P. Sardin (Engineer of the Civil Engineering Dept.-SETRA)

P. Bar (Engineer in charge of studies -SETRA)

assisted by R. Balle (technician).

It was submitted to the NOISE group assigned to the establishment of the Guide to the Noise of Ground Means of Transportation under the direction of Monsieur Engineer General Bideau, to be appended to that new guide.